

CONFERS On-Orbit Servicing (OOS) Mission Phases

1 Introduction

This document establishes a baseline of mission phases that is intended to describe the functions of all OOS missions. All phases do not apply to all OOS missions, but all OOS missions should find general descriptions of the functions of all of their phases. Functions or phases that are not unique to OOS missions are not included. For example, Collision Avoidance (COLA) procedures are continuously performed for all missions, and hence are not included in this document. Similarly, all phases require diligence in prevention of generating space debris, although some (e.g. servicing phases) more than others. Sometimes phase titles for such phases may be included with a note that explains that there is no content that is unique to OOS missions.

This document uses the CONFERS (currently draft) Lexicon for Rendezvous and Proximity Operations (RPO)/OOS Terms and Definitions. In particular, “Servicer” and “Client” refer to the organizations that perform servicing and client functions, respectively. When the term refers to the spacecraft, it will always use “Servicer Spacecraft” and “Client Space Object”, respectively.

The actions and responsibilities identified herein are assigned to the Servicer and Client organizations. If other organizations are required to fulfill the actions of a phase, it is the responsibility of the Servicer and Client organizations to secure those resources and ensure the required functions are performed.

2 Overview Diagram

The following figure is an overview of most of the key mission phases described in the following sections of this document.

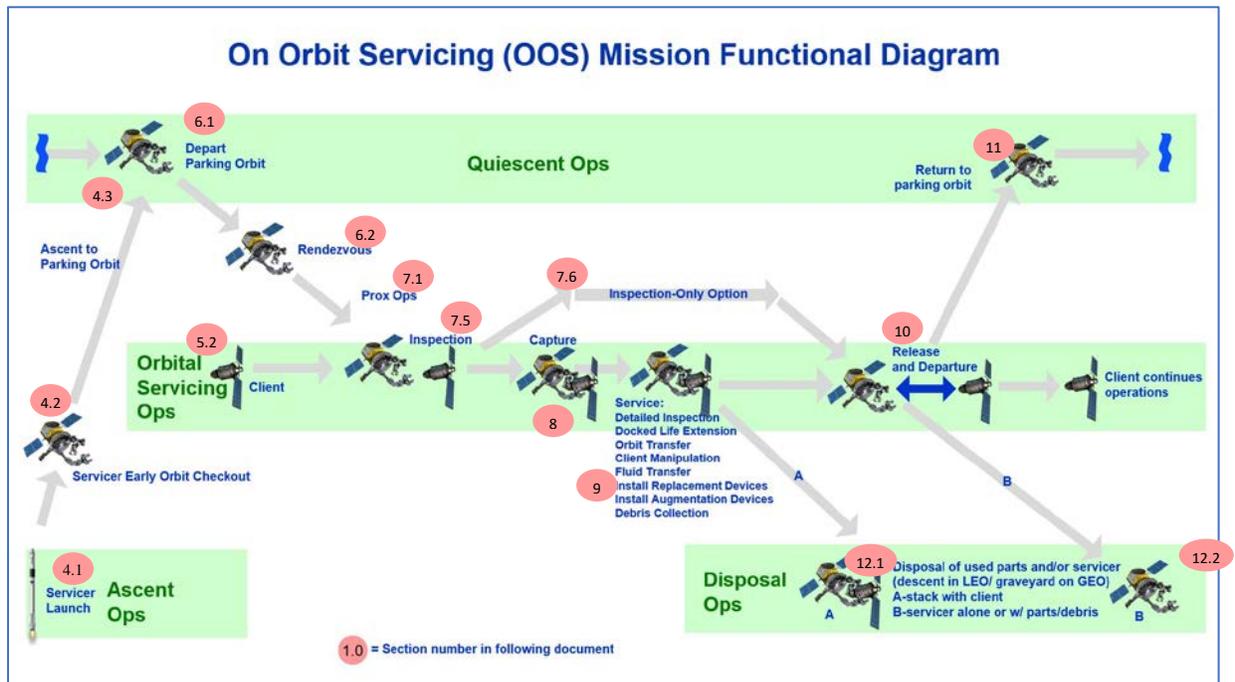


Figure 1: On-Orbit Servicing (OOS) Mission Functional Diagram.

3 Pre-Mission

3.1 Mission Assessment

Servicer and Client assess mission.

The Servicer and Client assess the needs of the Client Space Object against the capabilities of the Servicer Spacecraft and determine if there is adequate mutual interest to proceed with contracting.

3.2 Service Contracting.

The Servicer and Client establish servicing agreements and contracts which address, for example, risk assessment, insurance provision, etc.

3.3 Perform Compatibility Assessment

The Servicer and Client (and their supporting organizations) collect relevant data (including health of Client Space Object and Servicer Spacecraft) and perform analysis to ensure compatibility between the Servicer Spacecraft and the Client Space Object.

3.4 Service planning

The Servicer and Client exchange and coordinate servicing plans. They develop detailed sequence of events, operational procedures and contingency plans.

3.5 Inform and Coordinate with other stakeholders as appropriate

The Servicer and Client ensure necessary regulatory bodies and reasonably affected space actors are informed of the plan and intentions to the level of detail required to provide adequate transparency.

This phase may be executed in a different place of the timeline, for example, by different service providers.

3.6 Licensing

The Servicer and Clients coordinate and establish relevant licensing approvals from State Authorities as required.

3.7 Insurance

The Servicer and Client ensure adequate insurance is in place for their own interests and those of relevant 3rd parties.

3.8 Prepare Servicer Spacecraft, Client Space Object and associated operations systems

3.8.1 Design, build, test and launch Servicer Spacecraft and operations systems (if required)

When a new Servicer Spacecraft is required to be developed, the Servicer will design, assemble, and test the Servicing Vehicle according to Recommended Practices.

3.8.2 Update Servicer Spacecraft systems and supporting systems

When a Servicer Spacecraft is already on-orbit, the Servicer will (as needed) update Servicer flight software and operational procedure adaptations and tests.

3.8.3 Prepare Client Space Object and associated operations systems (if required)

Any required flight software adaptations on the Client Space Object or associated operations systems should be developed, tested and verified.

3.9 Train Mission Operations Team

The Servicer and Client will conduct training and mission simulations (standalone or joint) as required.

3.10 Servicer pre-launch ground ops (at the launch site)

This phase has no content that is unique to OOS missions. Normal spaceflight/spacecraft processes apply.

4 Launch and Prepare Servicer Spacecraft

If using a Servicer Spacecraft that is already in amenable orbit, skip this phase.

This phase consists of three subphases that place a Servicer Spacecraft in a position where it is ready to rendezvous with clients. The subphases are launch, commissioning, and quiescent operations.

4.1 Servicer Spacecraft Launch

The Servicer launches a Servicer Spacecraft into an initial orbit. The Servicer monitors systems during ascent.

4.2 Servicer Commissioning

The Servicer performs initial activation and checkout of the Servicer Spacecraft and verifies that the Servicer Spacecraft is ready for its mission(s).

4.3 Servicer Quiescent Operations

If the Servicer Spacecraft will rendezvous with the Client Space Object immediately, skip this subphase.

Following Servicer Spacecraft Commissioning or after departing a Client Space Object, if the Servicer Spacecraft is not immediately beginning rendezvous operations for its next Client Space Object, then it will enter Quiescent Operations before beginning Rendezvous Operations with the next Client.

A quiescent parking orbit may be any suitable orbit where a Servicer Spacecraft awaits between missions.

When a resupply station is present, the Servicer Spacecraft may rendezvous and dock with the resupply station, following a procedure like the phases that follow for Client Space Objects.

5 Client Operations Pre-Servicing

5.1 Reposition Client Space Object

If there is no need to reposition the Client Space Object, skip this phase.

The Client Space Object is transferred from its current orbit to the orbit in which it will be serviced by the Servicer Spacecraft. This includes pre-positioning or phasing of the Client Space Object's orbit to achieve the defined proximity operations control volume.

5.2 Client Quiescent Operations

The Client Space Object is assumed to be in an initial quiescent state before servicing operations begin.

The Client Space Object control center monitors the Client Space Object's state of health.

6 Rendezvous

A rendezvous is the series of actions taken by the Servicer Spacecraft to transition its orbit from the departure of the prior Client Space Object or from its parking orbit, to the desired rendezvous orbit.

6.1 Initiate Rendezvous Action

The Servicer Spacecraft initiates action to rendezvous with the Client Space Object by performing an orbital transfer or phasing maneuver to achieve the desired rendezvous orbit. This action marks the beginning of the Servicer Spacecraft's RPO operations.

6.2 Reposition Servicer Spacecraft to Client Space Object Vicinity

The Servicer Spacecraft performs additional orbital transfer and phasing maneuvers to achieve the desired RPO orbit.

This phase ends once the Servicer Spacecraft has achieved the outer limits of a pre-defined Proximity Operations Control Volume and phasing.

7 Proximity Operations

Proximity operations are those relative operations performed between the Servicer Spacecraft and the Client Space Object within a pre-defined Proximity Operations Control Volume. During this phase, separation between the two objects is typically controlled using on-board sensors to provide relative navigation.

7.1 Approach for Assessment

During this sub-phase, the Servicer Spacecraft may navigate around the Client Space Object, if necessary, to assess the status of the Client Space Object.

At some point during RPO, the Client Space Object will transition from its normal operations mode to a mode in support of servicing by the Servicer Spacecraft.

This phase may be executed in a different place of the timeline, for example, by different service providers.

7.2 Verification of Client Space Object Identity

During this phase, the Servicer should verify identity of the Client Space Object (some GEO slots have multiple authorized Resident Space Objects [RSOs], e.g., 19.2°E) which could be located within the proximity operations control volume.

This phase may be executed in a different place of the timeline, for example, by different service providers.

7.3 Way points

Way points are operational events generally used to:

- a) perform a specific operational function; and/or
- b) reconfigure the spacecraft for the next phase or sub-phase of the rendezvous; and/or
- c) assess status and readiness of the spacecraft for the next phase or sub-phase of the rendezvous

These events generally coincide with either the Servicer Spacecraft attaining a defined orbit relative to the Client Space Object, or freezing its location relative to the Client Space Object, or simply attaining a pre-identified point in time, event, or location. Frequently, such way points are used to coordinate and approve execution of the next phase or sub-phase of the servicing mission between the Servicer and the Client.

Way points may apply to and be performed in other phases as well.

7.4 Client Preparation

The Client Space Object may, if necessary and capable, adjust its attitude, its articulations, and its operational configuration in preparation for remote inspection or contact approach and capture.

7.5 Remote Inspection and Non-Contact Services

During this sub-phase, the Servicer Spacecraft acquires and records inspection data/images and sends them to the ground. The Servicer and Client ground team performs analysis and (if needed) re-planning based on the data/images. This sub-phase may also constitute a service to the Client by providing the inspection products to the Client. The Servicer may also provide other non-contact services such as wifi or other local communications (e.g. for software upgrades.)

7.6 Departure

This sub-phase is the departure from the Client Space Object Proximity Operations Control Volume upon completion of a non-contact Service or if the servicing mission is terminated as a result of new mission information.

8 Contact Approach and Capture

If the mission is for remote inspection only, this phase and others following are skipped.

The Servicer Spacecraft makes a final approach to contact the Client Space Object, and the Servicer Spacecraft and the Client Space Object make contact by various means, including docking, grappling, netting, and so forth. This phase includes three sub-phases of approach, capture and stabilization described below.

8.1 Approach

The Servicer Spacecraft makes a final approach to contact the Client Space Object. This approach typically will make use of way points in which the Servicer Spacecraft will hold position relative to the Client Space Object while configuration changes or assessments are made to confirm the next step of the approach. Approach concludes once the final command is issued to initiate Capture.

8.2 Capture

There are many techniques for achieving capture, each with unique phases and sub-phases and associated risks. Typically, these phases will include some form of initial contact and soft capture followed by rigidization. Prior to or during initial contact, some form of protection against electrostatic discharge between the Servicing Spacecraft and Client Space Object should be activated, enabled, or otherwise provided.

8.3 Post Capture Stabilization

Following rigidization, the new combined vehicle stack will be stabilized either by the Servicing Spacecraft or the Client Space Object, or both. This phase may also include a transition period to achieve a desired servicing attitude and reconfigurations of the Servicing Spacecraft and/or Client Space Object prior to the start of servicing operations.

9 Service

If the mission is for remote inspection only, skip this phase.

This phase consists of one or more of the following actions that require contact between the Servicer Spacecraft and the Client Space Object.

9.1 Detailed inspection

During this service, the Servicer Spacecraft acquires and records inspection data/images and sends them to the ground. The Servicer provides the service to the Client by providing the inspection products to the Client.

9.2 Docked Life Extension

The Servicer Spacecraft and the Client Space Object remain connected to function as a single vehicle. Operation and control of the mated stack is conducted for a duration per Client and Servicer agreements. Docked operations may continue for the lifetime of the Client Space Object. Various services may supplement Client systems or extend the Client Space Object's life. After this mission, the Servicer Spacecraft may go on to other servicing missions.

9.3 Orbit Transfer.

In this service, the Servicer Spacecraft may be used to transfer the Client Space Object (or only some of its removed components – see phase 9.6) to a new orbit instead of using the Client's on-board propulsion (if it has any).

This service may be used to assist with decommissioning a Client Space Object (but not the Servicer Spacecraft as discussed in phase 12). In this case the orbit transfer will be to either a graveyard orbit or a re-entry orbit. Functions include the operation and control of the mated stack and/or captured debris, and release of the Client/debris to the disposal orbit.

9.4 Client Manipulation

This service includes the manipulating/repositioning of components on the Client Space Object. For example, the Servicer Spacecraft may contact an articulated feature of the Client Space Object that failed to deploy, freeing it to deploy correctly. Functions of this phase may include operation and control of the mated stack, modification of the Client Space Object, or robotic correction of Client Space Object mechanical anomalies.

9.5 Fluid Transfer

This service includes transferring fluids (e.g. fuel, water, pressurant, etc.) from one space object to the other. Functions during the service include operation and control of the mated stack, transfer of fluid from the Servicer Spacecraft to the Client Space Object (or vice versa), or a fluid tank exchange. Note

that this service may include the Servicer Spacecraft retrieving fuel from the Client Space Object (or a fuel depot).

9.6 Installation of Replacement or Augmentation Devices

This service includes the attachment of new components or replacement of components on the Client Space Object. Devices may be launched separately and retrieved by the Servicer as if it were a CSO. Functions during the service include operation and control of the mated stack, removal and stowage of Client Space Object components, addition of new or replacement components on the Client Space Object, and disposal of the removed components. The complete service is then followed by phases 10, 9.3, and disposal of components in a specific orbit (graveyard or reentry).

9.7 “Debris” Collection and Removal

This service includes the collection of debris, including non-functioning Client Space Objects. In this case, the RPOC functions are with uncontrolled debris objects (note that these objects may be tumbling, which creates a new technical challenge for the servicer, especially during final approach and capture.) Functions during the service include operation and control of the mated stack, Orbit Transfer (9.3) of the debris, and disposal of the debris in a specific orbit (graveyard or reentry).

10 Release and Departure

The Servicer Spacecraft and the Client Space Object demate and separate to a safe distance before resuming independent operations.

11 Return to Quiescent Operations

The Servicer Spacecraft may return to quiescent operations.

12 Disposal

The Servicer Spacecraft may reposition to a disposal orbit, to dispose itself and any used parts or debris that it carries.

12.1 Disposal of Servicer Spacecraft by re-entry (may include Client Space Object and/or parts/debris)

In this operation the mated stack of the Servicer Spacecraft including any Client Space Object (and/or parts/debris) are disposed of by reentry. Functions during this phase include operation and control of the mated stack, orbit transfer to the re-entry orbit, reentry operations, and notification to affected states.

12.2 Disposal of Servicer Spacecraft in graveyard orbit (may include Client Space Object and/or parts/debris)

In this operation the mated stack of the Servicer Spacecraft including any Client Space Object (and/or parts/debris) are disposed of by repositioning to a graveyard orbit. Functions during this phase include operation and control of the mated stack, orbit transfer to the graveyard orbit, reconfiguration of the Servicer Spacecraft and any Client Space Object as appropriate for decommissioning, and notification to affected states.